



The Living Universe: NASA and the Development of Astrobiology

**Steven J. Dick
NASA Chief Historian
GSFC Library Open House
October 20, 2004**

Two Chief World Systems

17th Century

Geocentric vs. Heliocentric



DIALOGO
D I
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLO STUDIO DI PISA.
E Filosofo, e Matematico primario del
SERENISSIMO
GR.DVCA DI TOSCANA.

Due ne i congressi di quattro giornate si discorre
sopra i due

MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO;

*Proponendo indeterminatamente le ragioni Filosofiche, e Naturali
tanto per l'una, quanto per l'altra parte.*

CON PRI



VILEGI.

IN FIRENZA, Per Gio:Batista Landini MDCXXXII.

CON LICENZA DE' SUPERIORI.

Galileo – 1632

Two Chief World Systems 21st Century

The Physical Universe vs. The Biological Universe

Cosmic Evolution



Big Bang	Precambrian Biology
Galaxies	Complex Life
Stars	Intelligent Life
Biogenic Elements	Cultural Evolution
Planets	Civilizations
Chemical Evolution	Science and Technology
Origin of Life	Study of Life in the Universe

The Biological Universe: Controversial



Giordano Bruno
Piazza Campo dei Fiori
Rome

The Biological Universe: Long-Term Problem



Mid-17th century Jesuit view.
The Copernican system is still
Outweighed by the hybrid
Tychonic system. The geocentric
System is discarded at bottom.

Riccioli, *Almagestum Novum*, 1651

Astrobiology and the Biological Universe

- The Triumph of Cosmic Evolution
- Coalescence into a New Discipline
- Astrobiology Today
- Implications of a Biological Universe

The Triumph of Cosmic Evolution



A Universe 3600 Light Years in Extent

A. R. Wallace, 1903

MAN'S PLACE IN THE UNIVERSE

A STUDY OF THE RESULTS OF SCIENTIFIC RESEARCH IN RELATION TO THE UNITY OR PLURALITY OF WORLDS

BY

ALFRED R. WALLACE, LL.D., D.C.L., F.R.S.

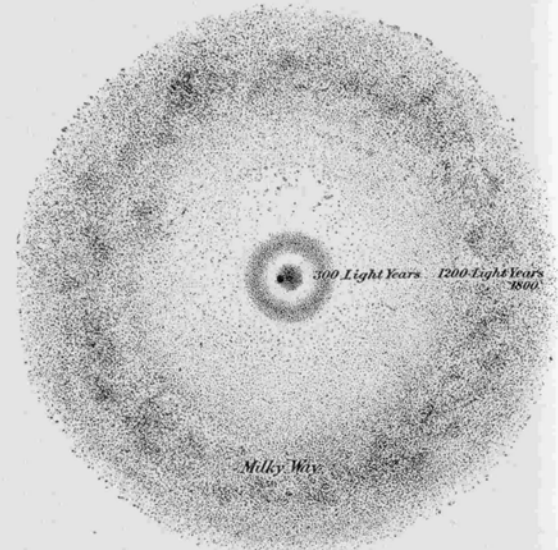


NEW YORK
McCLURE, PHILLIPS & CO.
MCMIII

296

MAN'S PLACE IN THE UNIVERSE

DIAGRAM OF STELLAR UNIVERSE (Plan)



1. Central part of Solar Cluster.
2. Sun's Orbit (black spot).
3. Outer limit of Solar Cluster.
4. Milky Way.

are on the same scale, and they show the total diameter across the Milky Way as being 3600 light-years, or about half that

A Universe Billions of Light Years in Extent

Late 20th Century

Hubble Deep Field, R. Williams, the HDF Team (STScI), NASA

Shapley on Cosmic Evolution



The Earth and its life are “on the outer fringe of one galaxy in a universe of millions of galaxies. Man becomes peripheral among the billions of stars in his own Milky Way; and according to the revelations of paleontology and geochemistry he is also exposed as a recent, and perhaps an ephemeral manifestation in the unrolling of cosmic time.”

Harlow Shapley
Of Stars and Men, 1958

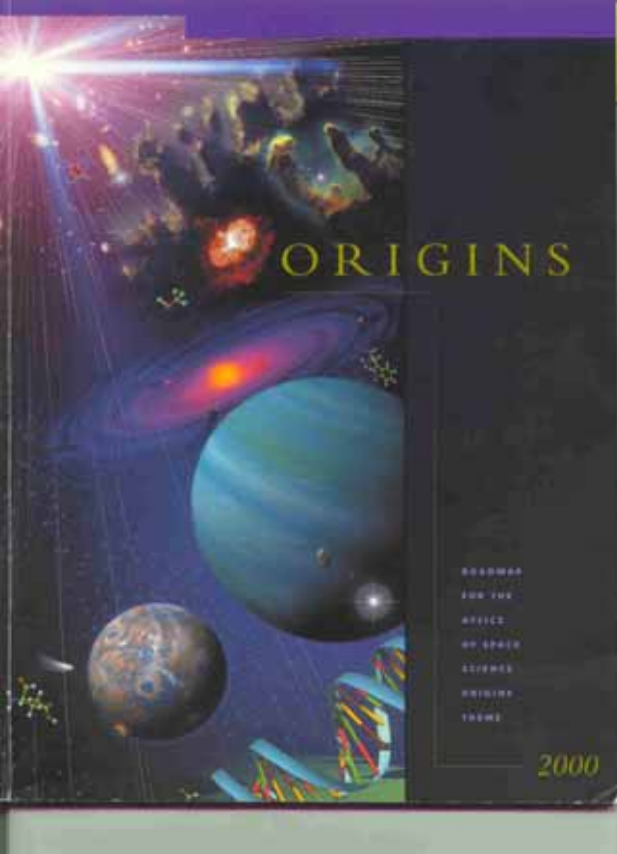
Cosmic Evolution



David DesMarais, Thomas Scattergood and Linda Jahnke/ NASA Ames, 1986, reissued 1997.



Cosmic Evolution according to NASA (1997)

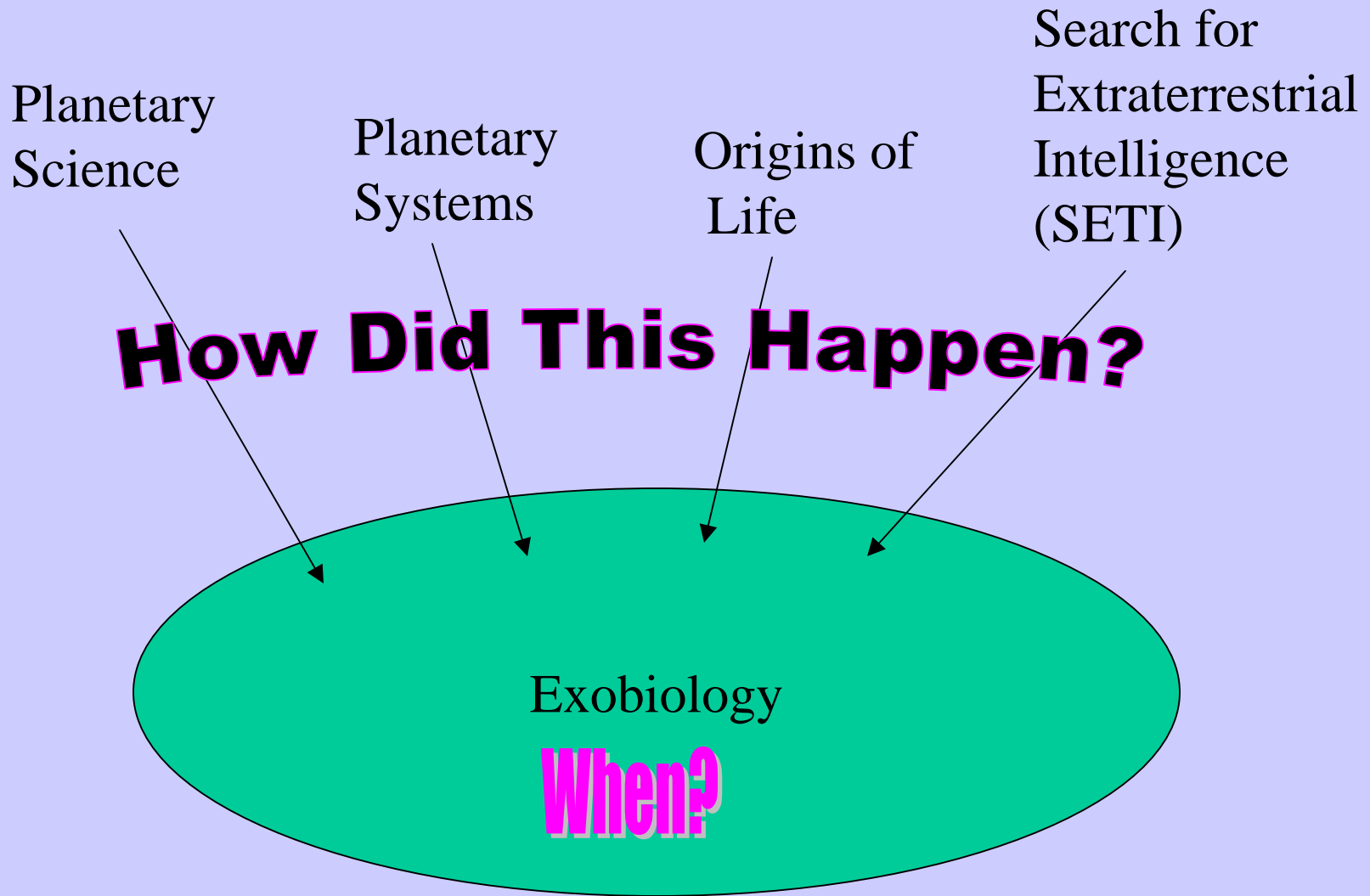


NASA and Cosmic Evolution

Following the 15 billion year long chain of events from the birth of the universe at the Big Bang, through the formation of chemical elements, galaxies, stars, and planets, through the mixing of chemicals and energy that cradles life on Earth, to the earliest self-replicating organisms – and the profusion of life

Coalescence of a New Discipline: Foundations of Exobiology To 1965

Coalescence of a New Discipline



Planetary Science: The Copernican Foundation

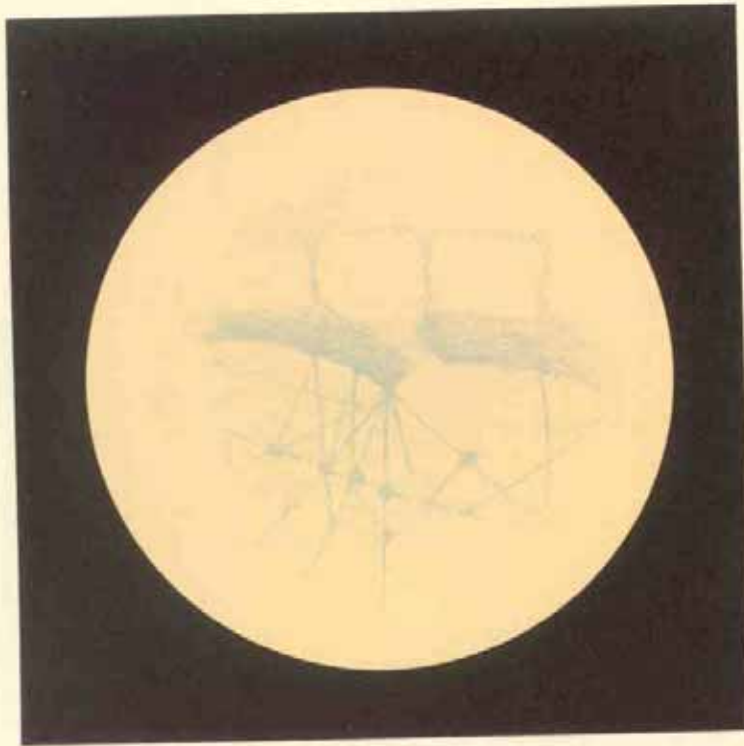
John Wilkins, *Discourse
Concerning a new World
And Another Planet* (1640)

The Moon and the planets
Are potential Earth-like worlds



Evidence of Life on Mars, 1894

PLATE I

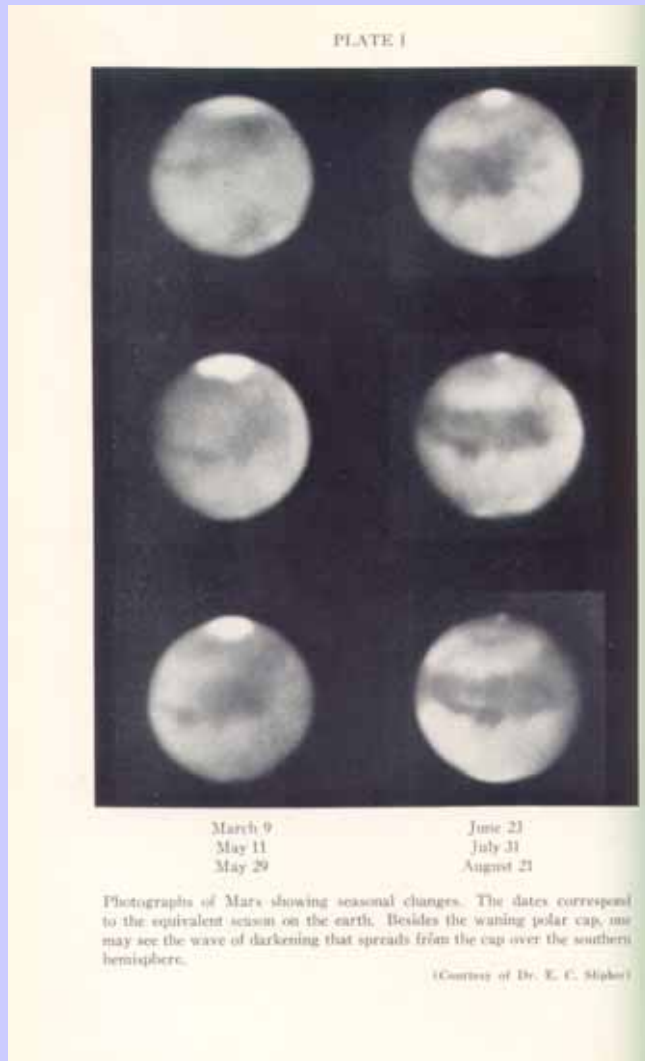


MARS
SINUS TITANUM
NOVEMBER, 1894

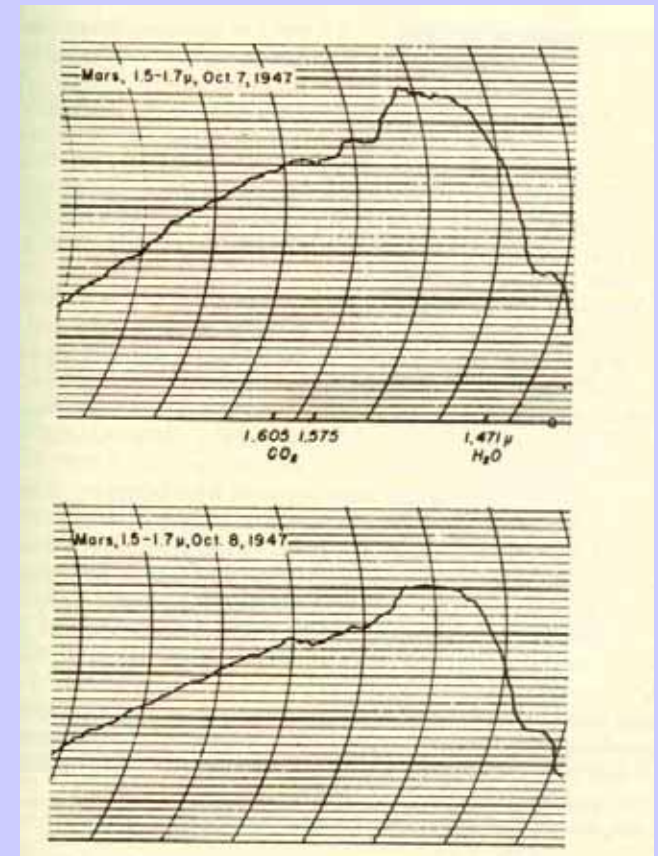
Lowell, *Mars* (1894)

Martian Vegetation?

Seasonal surface variations
E. C. Slipher, 1924-1926

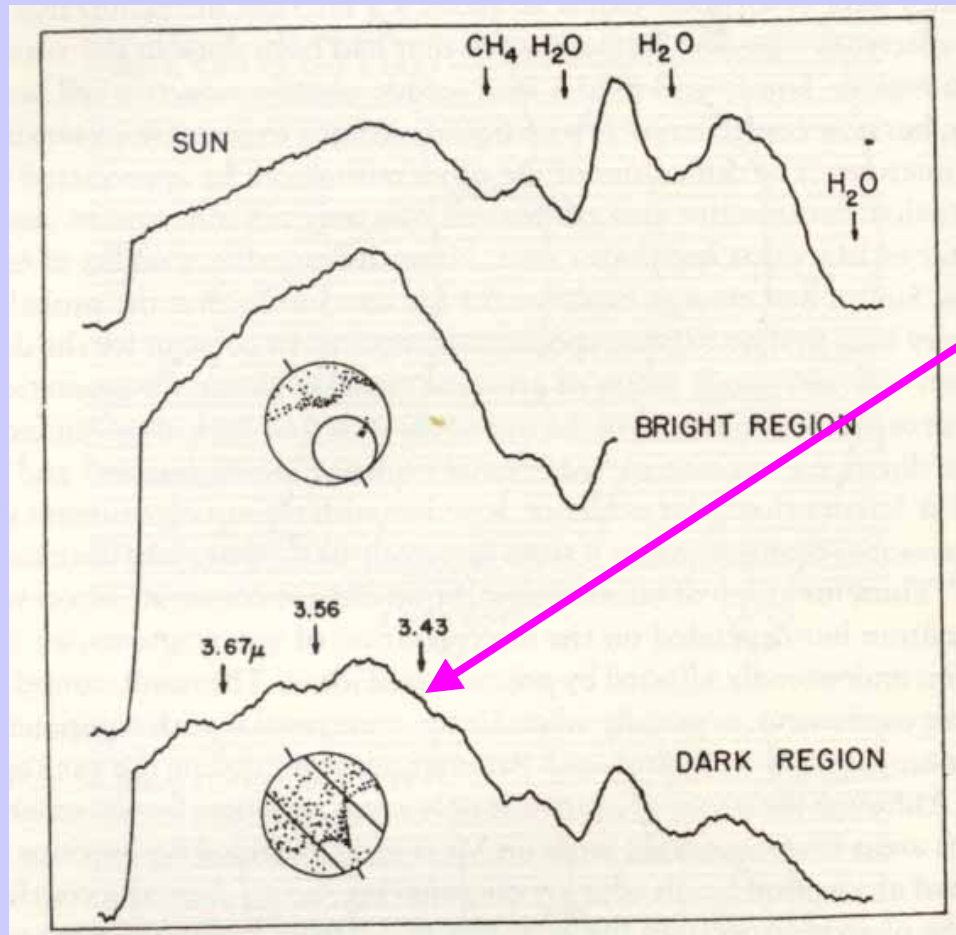


Kuiper – CO₂ on Mars, 1947
Plant life?



Carbon dioxide bands on
Mars in 1.6 micron region
Using infrared spectrometer on
McDonald 82-inch, 1947

Evidence of Life on Mars, 1959



Near-infrared absorptions
On dark areas of Mars
Interpreted as due to
vegetation

William Sinton,
“Further Evidence of
Vegetation on Mars,”
Science (Nov. 6, 1959).

First American Symposium on Astrobiology – 1957!

PROBLEMS COMMON TO THE FIELDS OF ASTRONOMY AND BIOLOGY:

A SYMPOSIUM*

INTRODUCTION

ALBERT G. WILSON†

Lowell Observatory, Flagstaff, Arizona, and The RAND Corporation, Santa Monica, California

Today specialization is the rule in science. It is no longer possible for the individual scientist to be master of several disciplines as it was 100 or even 50 years ago. Today it is extremely difficult to stay abreast of the developments in one discipline or in even a part of one discipline, and today's student of science must restrict the breadth of his training in order to reach in some limited area a level of proficiency that will allow him to make original contributions.

But important research problems extend themselves beyond the area of training of specialists, and nature does not make simple divisions of phenomena into astronomy, physics, chemistry, and biology. So today it is becoming increasingly necessary for the scientist to ignore the synthetic walls of his compartmentalized training and establish working contacts with colleagues in other disciplines if he is to cope successfully with many current problems. The advice of Dr. Melvin Calvin, Professor of Chemistry at the University of California, to his students puts the matter succinctly: "You must master a special discipline. But you must also learn to escape from that discipline when the need arises. If in your research you find something that arouses your curiosity, do not drop it simply because it requires knowledge of another science. Acquire what knowledge and skill you need, and enlist the collaboration of the other specialists to pursue knowledge wherever it may lead." Recent examples of such *de-specialization* include the collaboration of meteorologists and astronomers in the

* Papers given at the symposium on "Problems Common to the Fields of Astronomy and Biology," held at the Flagstaff meeting of the Astronomical Society of the Pacific, June 18, 1957.

† Now at The RAND Corporation, Santa Monica, California.

PROBLEMS IN ASTRONOMY AND BIOLOGY 43

of the School of Aviation Medicine of the United States Air Force and in 1949 he was appointed chief of the newly founded Department of Space Medicine at the School of Aviation Medicine, Randolph Air Force Base, Texas. On July 20, 1956, Hubertus Strughold became a citizen of the United States.

It is indeed an honor to have Dr. Strughold serve as chairman for this first American symposium in Astrobiology.

I. GENERAL REVIEW OF PROBLEMS COMMON TO THE FIELDS OF ASTRONOMY AND BIOLOGY

HUBERTUS STRUGHOLD

School of Aviation Medicine, USAF
Randolph Air Force Base, Texas

In modern science it is an interesting fact that border areas between well-established specialties have become more and more important, as evidenced by numerous examples. Such interdisciplinary studies are of benefit to both of the partner disciplines.

Recently, an intermediate field between astronomy and biology has taken shape and has been given the name Astrobiology, which deals with the problems of life on other celestial bodies. Actually, the scope of the problems common to astronomy and biology is much broader when we include human physiology in planetary ecological considerations and the human factor involved in astronomical observations. This symposium is the first of its kind to cover, in special papers, the area in which astronomy and biology can work together fruitfully.

Questions involving both astronomy and biology were posed for the first time when in 1877 Schiaparelli of Milan discovered the features on Mars that were named by him *canali*. This started the discussion of life on other planets that reached its climax in the publications of Lowell. The progress made in rocketry, space technology, and space medicine in recent years has had a catalytic effect upon the interest in this problem, and its discussion has been in full tide ever since, with crests during oppositions of Mars.

Astrobiology is actually ecology, and extends geographic ecol-

Strughold
Dollfus
Sinton
Etc.

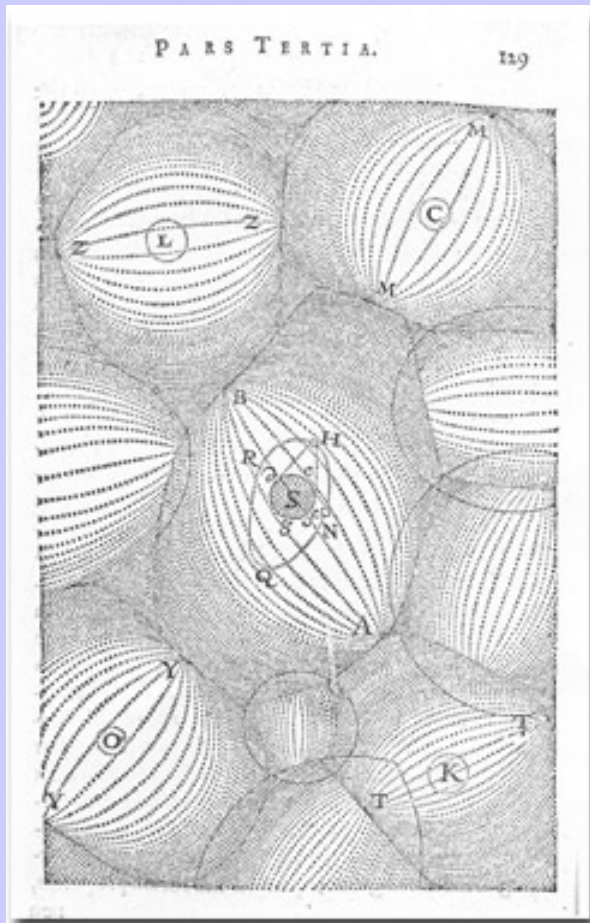
PASP, 70 (1958), 41-78

Exploration by Spacecraft

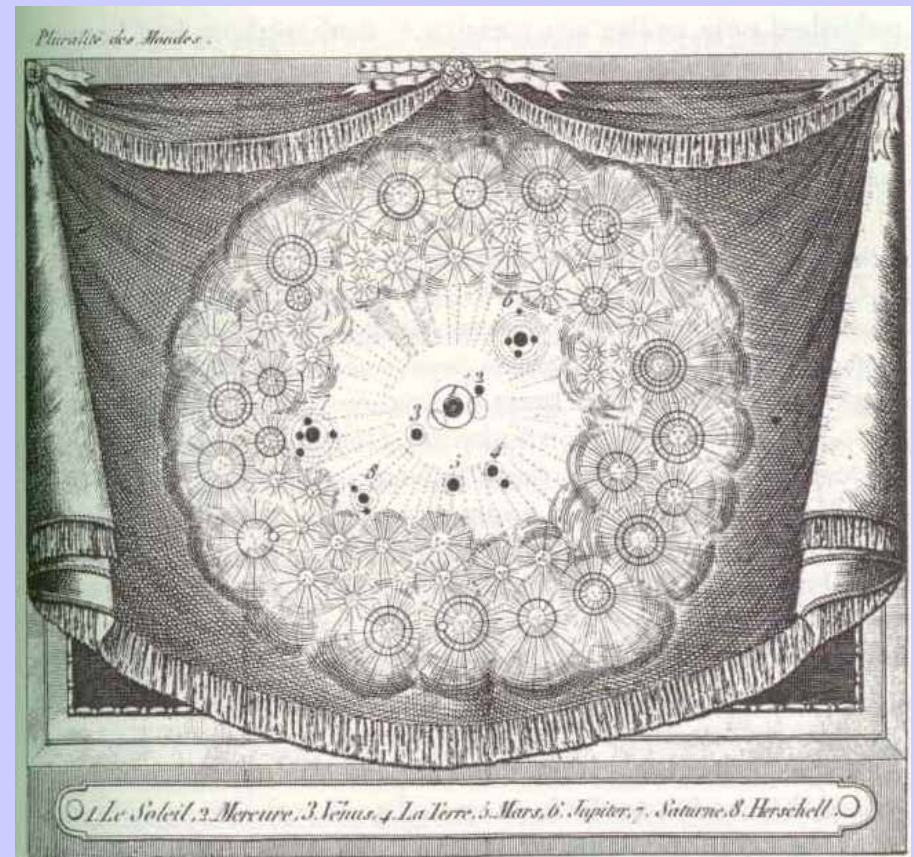


- Lederberg and planetary contamination issue leads to “Exobiology”
- NASA sets up life science lab at Ames
- Space Science Board/NAS sets search for extraterrestrial life as “prime goal of space biology.”
- Exploration of Mars by spacecraft begins

Planetary Systems – The 17th Century Foundation

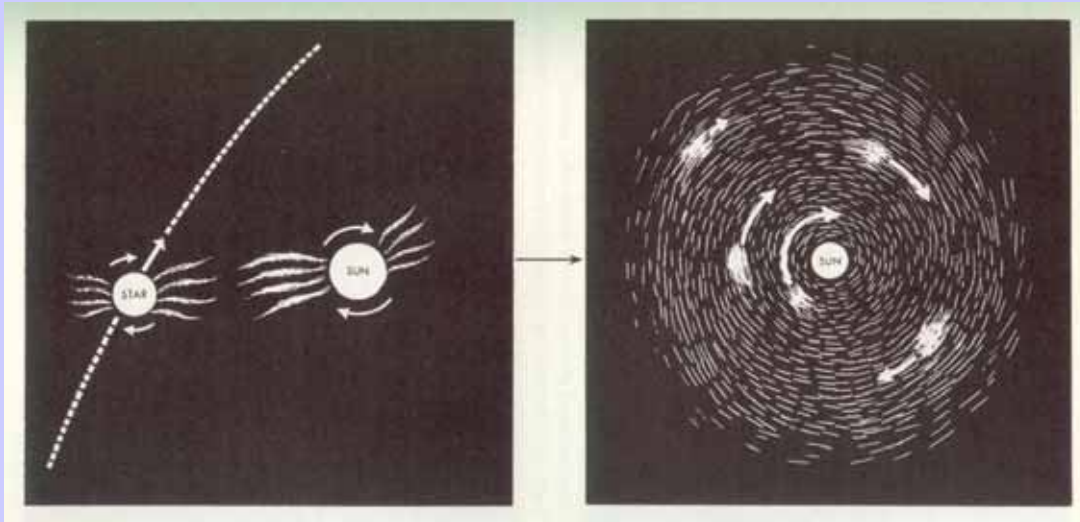


Descartes, 1644

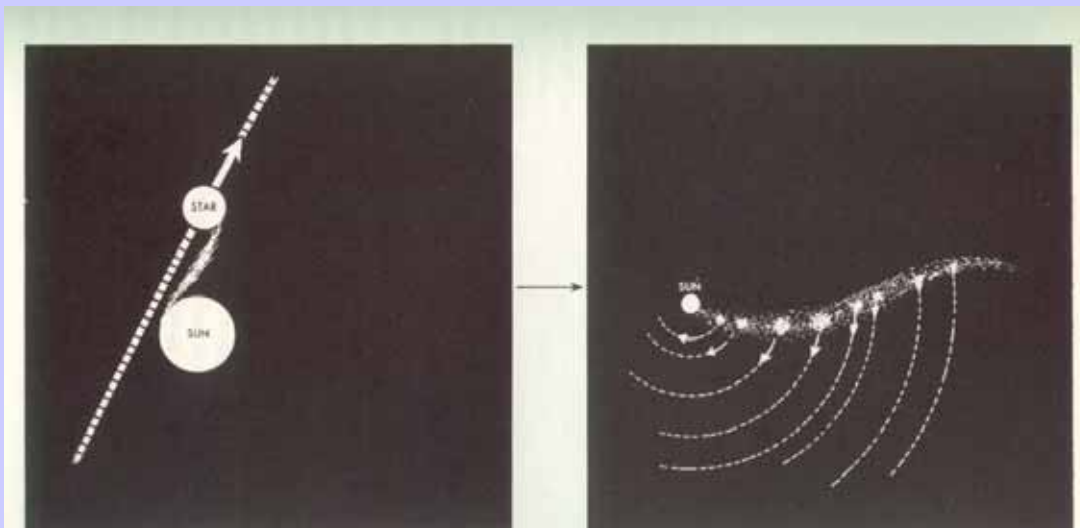


Fontenelle, 1686 (1821 ed.)

Tidal Hypothesis vs Nebular Hypothesis



Chamberlin-Moulton
(1905)



Jeans-Jeffreys
(1917)

From Thornton Page,
Physics Today (October, 1948)

Planetary Systems – Turning Point

Table 2.2 Estimates of Frequency of Planetary Systems, 1920-1961

Author	Argument	No. of planetary Systems in galaxy	No. of habitable planets in galaxy
Jeans (1919, 1923)	Tidal theory	Unique	1
Shapley (1923)	Tidal theory	“Unlikely”	“Uncommon”
Russell (1926)	Tidal theory “Speculation”	“Infrequent”	
Jeans (1941)	No. of stars	10^2	-
Jeans (1942)	Improved tidal Abundant	One in six stars	
Russell (1943)	Companions	Very large	$> 10^3$
Page (1948)	Weizsäcker	$> 10^9$	$> 10^6$
Struve (1950)	Stellar rotation		
Kuiper (1951)	Binary star statistics	10^9	-
Hoyle (1955)	Stellar rotation	10^{11}	-
Shapley (1958)	Nebular hypothesis	10^6 - 10^9	-
Huang (1950)	Stellar rotation	10^9	10^9
Hoyle (1960)	Stellar rotation	10^{11}	10^9
Struve (1961)	Stellar rotation	$> 10^9$	-

Adapted from Dick (1996), p. 199

Radial Velocity Planet Search – 1952!

October 1952 *High-Precision Stellar Radial Velocity Work*

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there is a good chance that by using somewhat larger equipment at the next eclipse, definite and accurate measurements of line width will become available.

I should like to say here how indebted we are to Professor Redman who at very short notice acquired a site for us at Khartoum and without whose assistance we should hardly have been able to set up our instruments in the short time available to us.

Mr. Sadler. I ask you to return your thanks to Prof. Brück and to all those who have taken part in this Colloquium. It is my task to predict eclipses, not to observe them but we have all found these preliminary accounts of the results expected, with varying degrees of optimism, most interesting. The meeting is now adjourned at 12^h 40^m.

PROPOSAL FOR A PROJECT OF HIGH-PRECISION STELLAR RADIAL VELOCITY WORK

By Otto Struve

With the completion of the great radial-velocity programmes of the major observatories, the impression seems to have gained ground that the measurement of Doppler displacements in stellar spectra is less important at the present time than it was prior to the completion of R. E. Wilson's new radial-velocity catalogue.

I believe that this impression is incorrect, and I should like to support my contention by presenting a proposal for the solution of a characteristic astrophysical problem.

One of the burning questions of astronomy deals with the frequency of planet-like bodies in the galaxy which belong to stars other than the Sun. K. A. Strand's¹ discovery of a planet-like companion in the system of 61 Cygni, which was recently confirmed by A. N. Deitch² at Poulkovo, and similar results announced for other stars by P. Van de Kamp³ and D. Reuyl and E. Holmberg⁴ have stimulated interest in this problem. I have suggested elsewhere that the absence of rapid axial rotation in all normal solar-type stars (the only rapidly-rotating G and K stars are either W Ursae Majoris binaries or T Tauri nebular variables,⁵ or they possess peculiar spectra⁶) suggests that these stars have somehow converted their angular momentum of axial rotation into angular momentum of orbital motions of planets. Hence, there may be many objects of planet-like character in the galaxy.

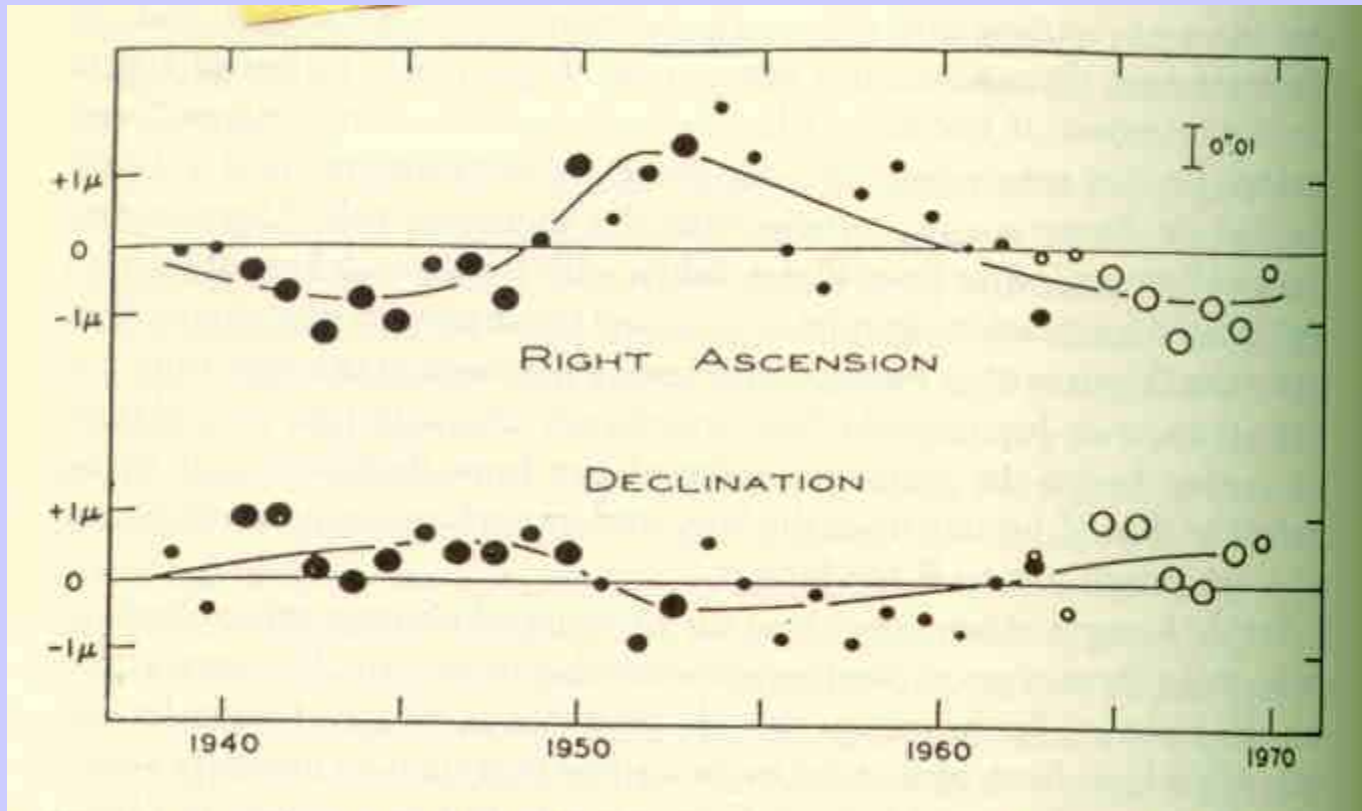
But how should we proceed to detect them? The method of direct photography used by Strand is, of course, excellent for nearby binary



- Suggests planetary companions might exist with 1 day period!
- Resulting in radial velocity oscillations of 200 m/sec for Jupiter mass planet.
- Detectable with Coude spectrograph
- Eclipses resulting in .02 mag dip!

Observatory, 72 (1952), 199

Van de Kamp's Claim



Barnard's Star
AJ, 1963

Origins of Life



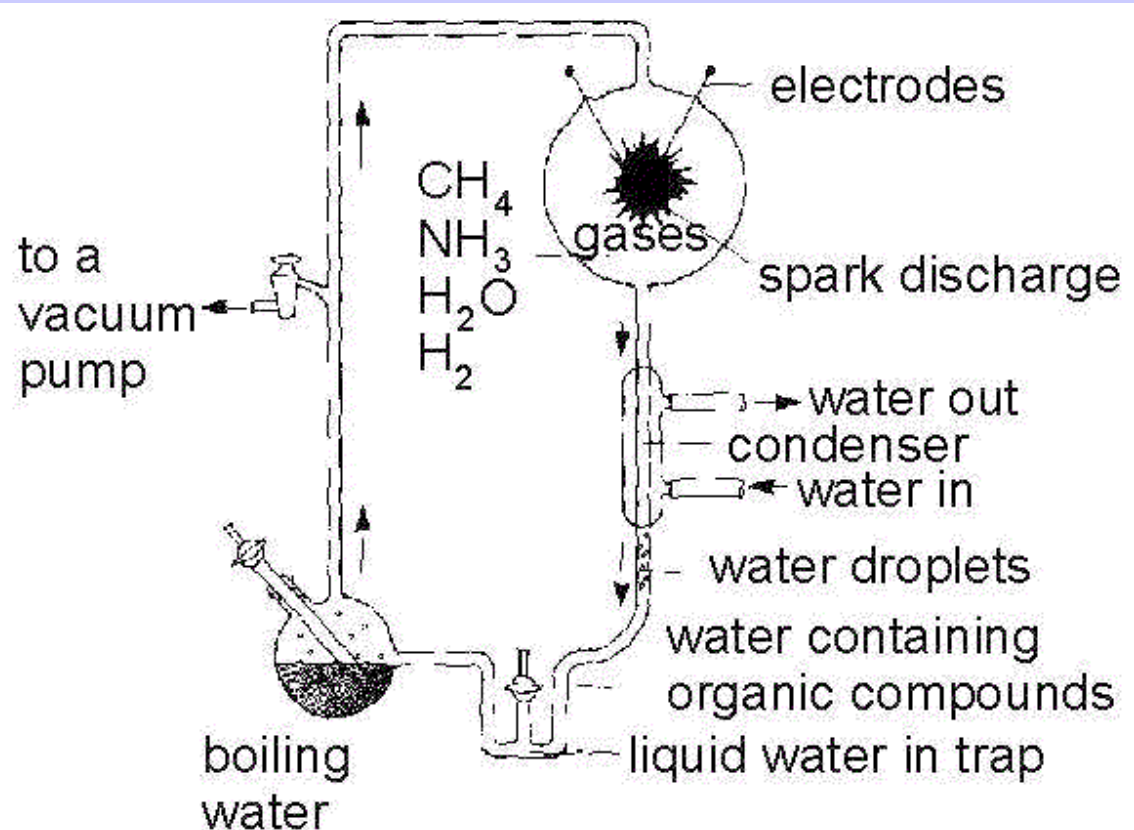
Alex. I. Oparin
Bill Schopf

Origins of Life



Miller-Urey Experiment, 1953

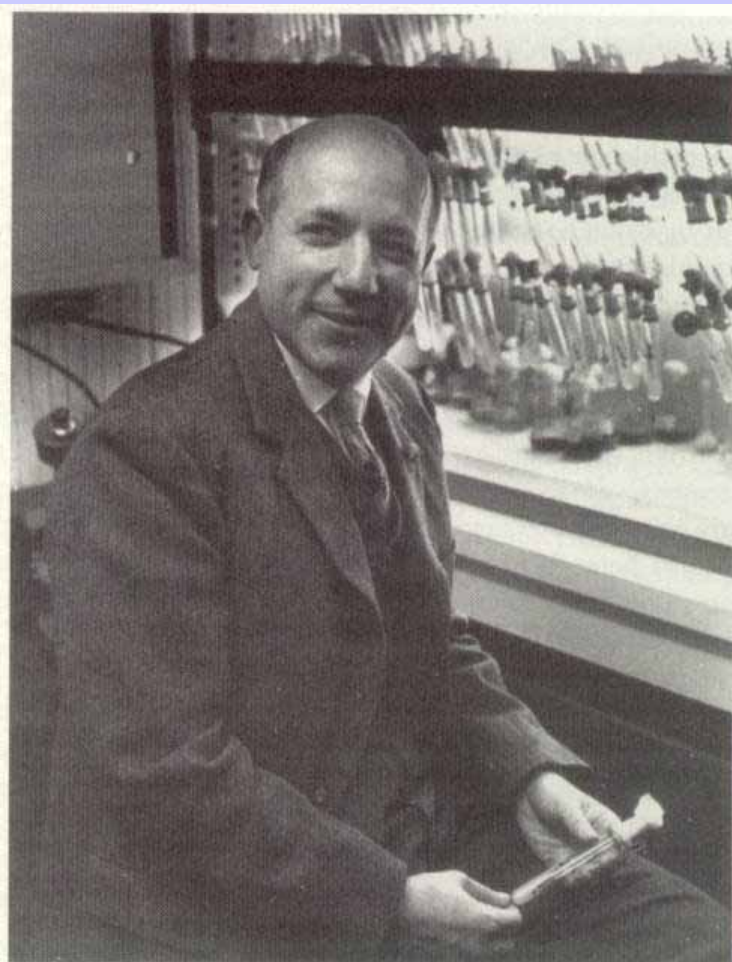
Synthesis of amino acids in
A presumed primitive Earth
atmosphere (methane and
ammonia)



Origins of Life and Astrobiology: The Inseparable Connection

**Surely one of the most marvelous feats of the 20th century
Would be the firm proof that life exists on another planet.
All the projected space flights and the high costs of such
developments would be fully justified if they were able to
establish the existence of life on either Mars or Venus. In that
case, the thesis that life develops spontaneously when the conditions
are favorable would be far more firmly established, and our whole
view of the problem of the origin of life would be confirmed.**

Miller and Urey, 1959



**Melvin Calvin, Prof. Of Chemistry
University of California**

Nobelist for work on photosynthesis

**“You must master a special discipline.
But you must also learn to escape from
That discipline when the need arises.
If in your research you find something
That arouses your curiosity, do not drop
It simply because it requires knowledge
Of another science. Acquire what
Knowledge and skill you need, and
Enlist the collaboration of the other
Specialists to pursue knowledge
Wherever it may lead”**

RADIO TO STARS, MARCONI'S HOPE

Inventor Says Waves of Ether
Are Eternal and Can Reach
Other Planets.

GETS STRANGE SIGNALS NOW

These, He Declares, Might Con-
ceivably Have Proceeded
from Other Worlds.

Special Cable to THE NEW YORK TIMES.
LONDON, Jan. 20.—The Daily Chroni-
cle publishes an interview which Harold
Begbie had with William Marconi, in
the course of which the latter discussed
the possibility of communicating by
wireless with the stars.

Mr. Begbie asked him if he thought
that waves of ether were eternal. Mr.
Marconi replied:

"Yes, I do. Messages that I sent off
ten years ago have not yet reached some
of the nearest stars. When they ar-
rive there why should they stop? It is
like an attempt to express one-third as
a decimal fraction; you can go on for-
ever without coming to any sign of an
end. That is what makes me hope for a
very big thing in the future."

"What is that?" asked Mr. Begbie.

SETI - Search for Extraterrestrial Intelligence

SHORT WAVE & TELEVISION for DECEMBER, 1937

Can We Signal MARS The Possibility of Interplanetary Communication

Including the Views of Dr. Lee de Forest and Nikola Tesla

THE possibility that intelligent life exists somewhere else in the universe than on earth is an intriguing subject. The possibility that we might communicate with some other intelligent beings is even more exciting. There is one prime test for the existence of life as we know it, on the earth; the existence of liquid water. Water, apparently, is the one most important constituent of all cells. Oxygen is not necessary, since plants exist on carbon dioxide. But even carbon is absolutely necessary, since certain bacteria have been found that are composed chiefly of sulphur. Presumably, however, carbon would be necessary for any higher form of life, owing to the peculiar chemical property of that element in being able to string itself together with atoms of oxygen and hydrogen in long and complex chains to form protoplasmic cell-bases. But water, in the liquid state, is absolutely necessary. Water, because of its peculiar physical and chemical properties, could not be replaced by any other solvent.

Consequently, when we wish to examine the possibility of the planets being inhabited, we must first investigate whether liquid water could exist on the planets. For this reason, both the moon and Mercury can be dismissed. Both of these are too hot on their sunward side and too cold on the night side. We may also dismiss the smaller planets, the asteroids, which are so small that water would have completely disappeared from their surfaces.

Jupiter, Saturn, Uranus, Neptune, and Pluto may also be dismissed from the realm of possibility. These planets, being so far from the sun are all too cold to support life. The temperature that has been found for Jupiter, the planet nearest to the sun of this group, is more than a hundred degrees below zero centigrade. The temperatures of the other planets are not so far from the freezing point of water as to make it probable that intelligent life exists in our solar system.

The picture at the left indicates that a veritable world of water is required in order to reach the short-wave signal to a planet such as Mars. It is a fact that a signal would be required to penetrate the atmosphere of a planet, and that the terrestrial conditions seem to have been more or less



approach obviously, must be indirect. What is Necessary to Support Life?

First of all, we may survey the known planets and regard the relative likelihood of their being inhabited. There is one prime test for the existence of life as we know it, on the earth; the existence of liquid water. Water, apparently, is the one most important constituent of all cells. Oxygen is not necessary, since plants exist on carbon dioxide. But even carbon is absolutely necessary, since certain bacteria have been found that are composed chiefly of sulphur. Presumably, however, carbon would be necessary for any higher form of life, owing to the peculiar chemical property of that element in being able to string itself together with atoms of oxygen and hydrogen in long and complex chains to form protoplasmic cell-bases. But water, in the liquid state, is absolutely necessary. Water, because of its peculiar physical and chemical properties, could not be replaced by any other solvent.

liquid air. We could have disintegrated these major planets on other grounds, mainly the presence of such gases as ammonia and methane in their atmospheres, which would not be very conducive to the existence of life.

Mars and Venus

In the solar system there remain, aside from the earth, only two possibilities. Mars and Venus. Of these, Mars has been the most publicized concerning the possibility of its being inhabited. We can study Mars much more readily than we can Venus because the atmosphere of Mars is very thin and our telescopes can penetrate to the surface. From the meagre observational data at our disposal, we can construct a picture of the planet and surface of Mars. Most of the planet consists of bare red rock, possibly broken, and possibly red sand. I like to think of this condition as approaching that of our painted desert in Arizona. At either pole of the planet we find water, congealed in the form of snow. These polar caps dwindle in size with the Martian summer and consequently we have reason to suspect that liquid water is present on one or two portions of the planet at some time during the year.

There are, also, dark markings, most prominent in the southern hemisphere of the Martian equator. The most surprising fact is that these dark markings change in size and also in color with the seasons. Sometimes they are grey-green and at other times brown. The changing form and coloration could, perhaps, be explained as the result of natural causes. It has been suggested, for example, that the changes are due to the presence of vegetation, on an absorbing water, change in the changing of the seasons. This explanation is entirely reasonable, but I prefer to account the changes as the result of vegetation. We can give no picture of Martian vegetation as we do not know whether the vegetation is in the form of trees, shrubbery, or merely minute organism like algae. Of course, when vegetable life is found, animal life may also occur, but the general conception of organic life on any higher degree of intelligent life exists in our solar system.

What is Necessary to Support Life?

First of all, we may survey the known planets and regard the relative likelihood of their being inhabited. There is one prime test for the existence of life as we know it, on the earth; the existence of liquid water. Water, apparently, is the one most important constituent of all cells. Oxygen is not necessary, since plants exist on carbon dioxide. But even carbon is absolutely necessary, since certain bacteria have been found that are composed chiefly of sulphur. Presumably, however, carbon would be necessary for any higher form of life, owing to the peculiar chemical property of that element in being able to string itself together with atoms of oxygen and hydrogen in long and complex chains to form protoplasmic cell-bases. But water, in the liquid state, is absolutely necessary. Water, because of its peculiar physical and chemical properties, could not be replaced by any other solvent.

SHORT WAVE & TELEVISION for DECEMBER, 1937

by Short Wave?

By Dr. Donald H. Menzel
Associate Professor of Astronomy, Harvard University.

THE question of radio-communication with distant planets still holds supreme charm for all red-blooded radio experimenters. First of course, is the question of the possibility of life existing on such planets as Mars, and we have asked the well-known authority, Dr. Menzel to answer this question. The amount of radio power required would probably be about 50,000 kilowatts the wavelength possibly as low as one centimeter (four-tenths of an inch).

What then? The chances are, that radio messages to outside space can be sent in only one way: "Noddy home." But we should not at some future date, receive bona-fide radio signals from outside the earth, what then? We could absolutely verify their extra-terrestrial character and perhaps even determine the actual source by means of direction finders. But could we hope to read the messages and enter into intelligible communication with beings on a distant planet? The archaeologists who read the Maya inscriptions had the advantage of knowing something of their origin, and especially of seeing drawings associated with the writing to indicate something of the nature of the text.

Don't fail to read Joseph R. K. Menzel's technical analysis of the problem of television in the early stages of development. It is a very interesting and useful book. See page 412.

A message has come to us, to be definite, let us say, from Mars. It consists of dots and dashes. The phrase would be of no significance to us unless we had a knowledge of the meaning of the dots and dashes. We have built powerful sending stations with directional antennas. Our own messages to them have been repeated, although we know that it is unprofitable to them. We understand that they hear us. How can we proceed to communicate with beings that have nothing in common with us earth-dwellers? That statement is clearly untrue. If we are in communication with one, we are in communication with both.

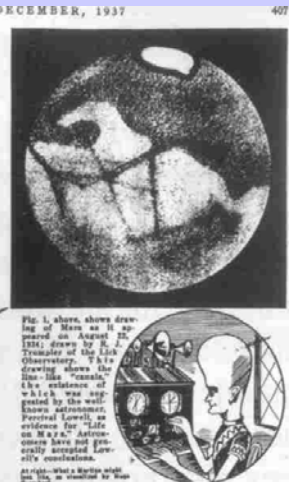


Fig. 1. above, shows drawing of Mars as it might appear, according to August 25, 1937, data by J. J. Truettner of the Lick Observatory. This drawing shows the line-like "canals" the existence of which was suggested by the well-known astronomer, Percival Lowell, as evidence for "life on Mars." Actual astronomical observations have not generally accepted Lowell's conclusion. An artist's sketch of Mars, as it might appear, is shown at right.

Nikola Tesla's Opinion On Martian Communication

NIKOLA TESLA, one of the greatest scientists of all time, recently made the statement that he believed that he had heard signals from a distant planet, nearly forty years ago.

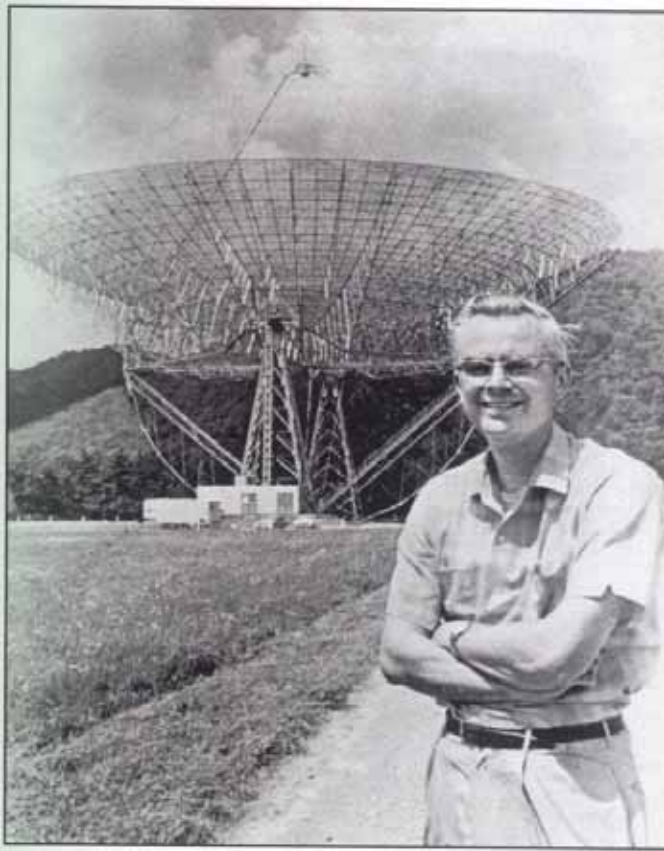
In about the year 1898, he was making a series of careful listening tests on short waves, when he heard a series of signals which had a peculiar measured character, and which were repeated every day. Tesla's interpretation of these signals was that they came from "U. S. A. etc." It is his opinion that if these signals had been sent by Martians, they had sent numbers in an attempt to establish communication with earth, for the great reason that numbers are one of the very first things learned by man.

Dr. Tesla was one of the earliest to believe in the possibility of communication with other planets, and about fifty years ago even before the year 1900, he was predicting that there would be a short-wave communication with the planets. He was one of the first to suggest that the use of the high-frequency radio and radio should go to Dr. Tesla. His early predictions were verified a number of times, and he was one of the first to suggest that the use of the high-frequency radio and radio should go to Dr. Tesla. His early predictions were verified a number of times, and he was one of the first to suggest that the use of the high-frequency radio and radio should go to Dr. Tesla.

Menzel, Shortwave & Television, 1937

Marconi, New York Times, 1920

SETI – Project Ozma



**300-foot
(later destroyed by aliens)**



**Project Ozma Team reassembled for the
25th anniversary, 1975 in front of the
85-foot Tatel telescope.**

The Drake Equation

Astronomical

Biological

Cultural

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Coalescence of a New Discipline

**Planetary
Science**

**Planetary
Systems**

**Origins of
Life**

**Search for
Extraterrestrial
Intelligence
(SETI)**

Sinton (1957)

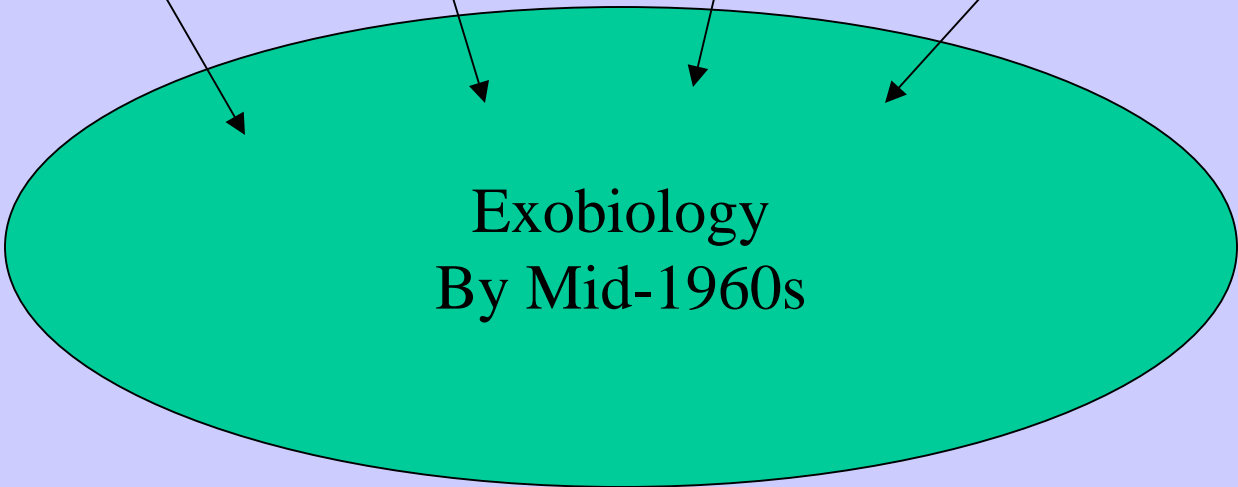
Lederberg (1960)

SSB (1962)

Van de Kamp
(1963)

Miller –Urey
(1953)

Drake/Ozma
(1960)



The diagram illustrates the convergence of four scientific fields into a single discipline. At the top, four categories are listed: Planetary Science, Planetary Systems, Origins of Life, and Search for Extraterrestrial Intelligence (SETI). Below each category, specific milestones are noted: Sinton (1957), Lederberg (1960), and SSB (1962) for Planetary Science; Van de Kamp (1963) for Planetary Systems; Miller –Urey (1953) for Origins of Life; and Drake/Ozma (1960) for SETI. Arrows from each of these milestones point towards a large green oval at the bottom. Inside this oval, the text 'Exobiology By Mid-1960s' is written, indicating the point of convergence.

**Exobiology
By Mid-1960s**

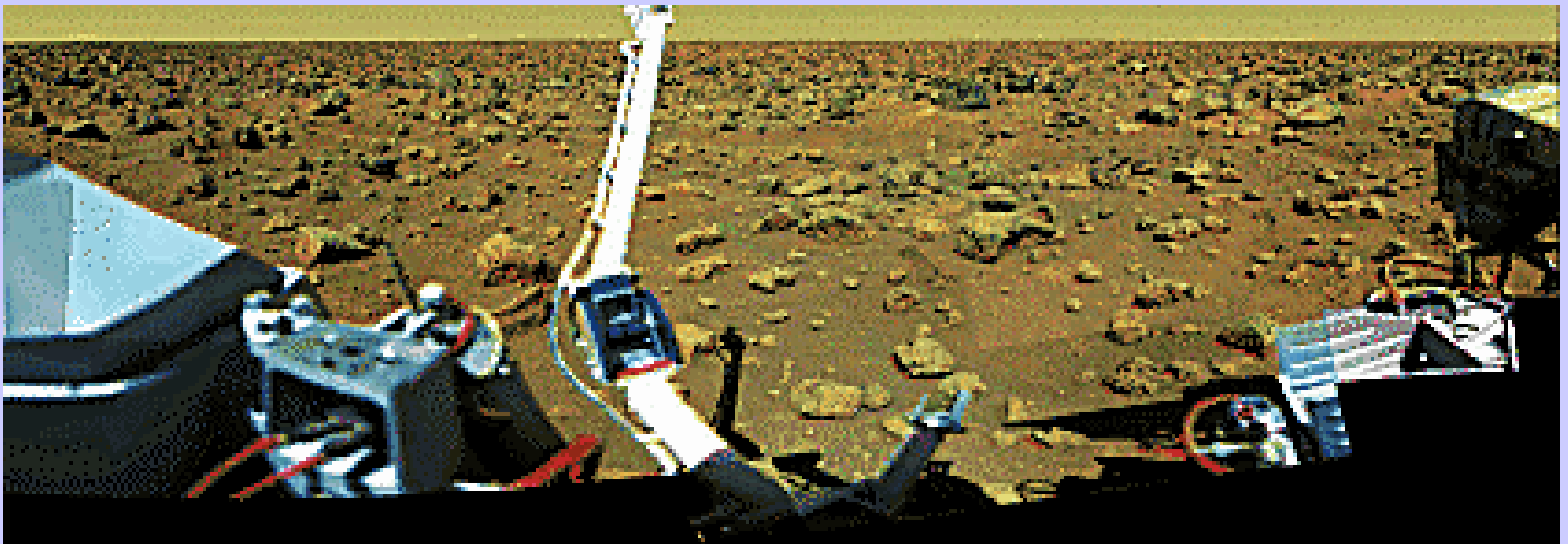
Declarations of a Discipline

- **Otto Struve on “astrobiology” (1955): “The time is probably not yet ripe to recognize such a completely new discipline within the framework of astronomy”**
- **Joshua Lederberg (1960): Sets the agenda and coins the term “exobiology”, “Exobiology: Experimental Approaches to Life Beyond Earth,” Science, 132 (1960).**
- **I. S. Shklovskii (1965): “we are witnessing the inception of a new science, which occupies a boundary position between astrophysics, biology, engineering and even sociology”**

Astrobiology

A Discipline Revitalized

Viking Results

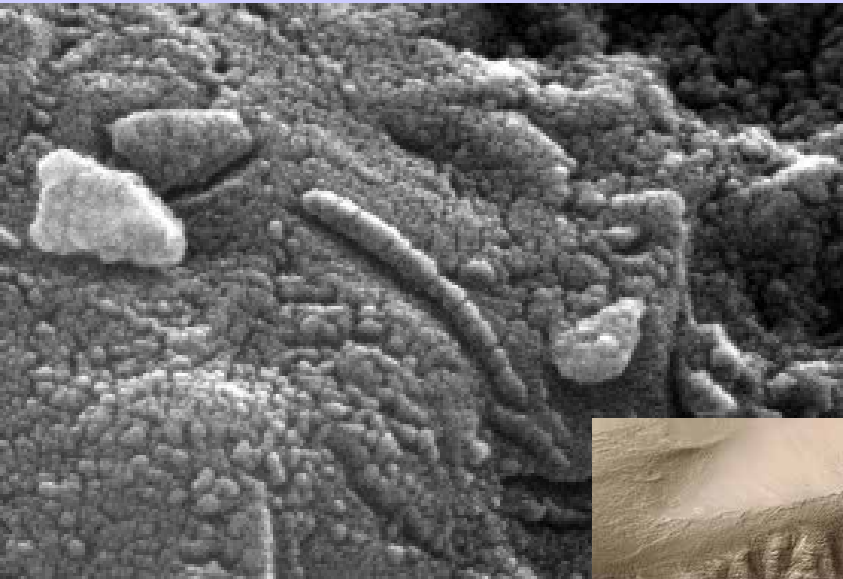


NASA and the Post-Viking Revolutions

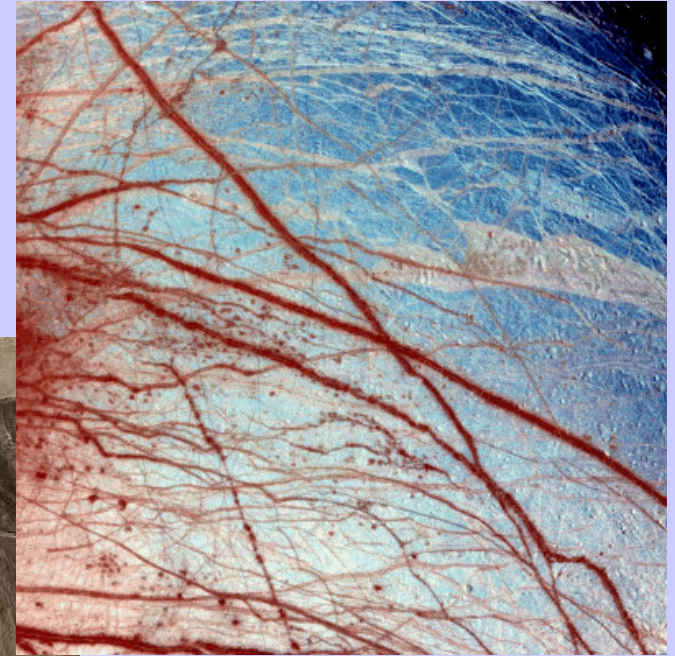
Exobiology Program Funded:

- ❖ Three Domains of life Research (Woese)
- ❖ Precambrian microfossils (Barghoorn and Schof)
- ❖ Gaia hypothesis (Lovelock and Margulis)
- ❖ Mass extinction work (Alvarez, Raup and Sepkoski)
- ❖ Exogenous Delivery (Sagan and Chyba)
- ❖ Pre-RNA world (Miller/NSCORT group)

Planetary Science



D. McKay,
K. Thomas-Keprta, R. Zare
Mars Rock fossils?



Cracked Ice Plains of Europa
Galileo Project, JPL, NASA

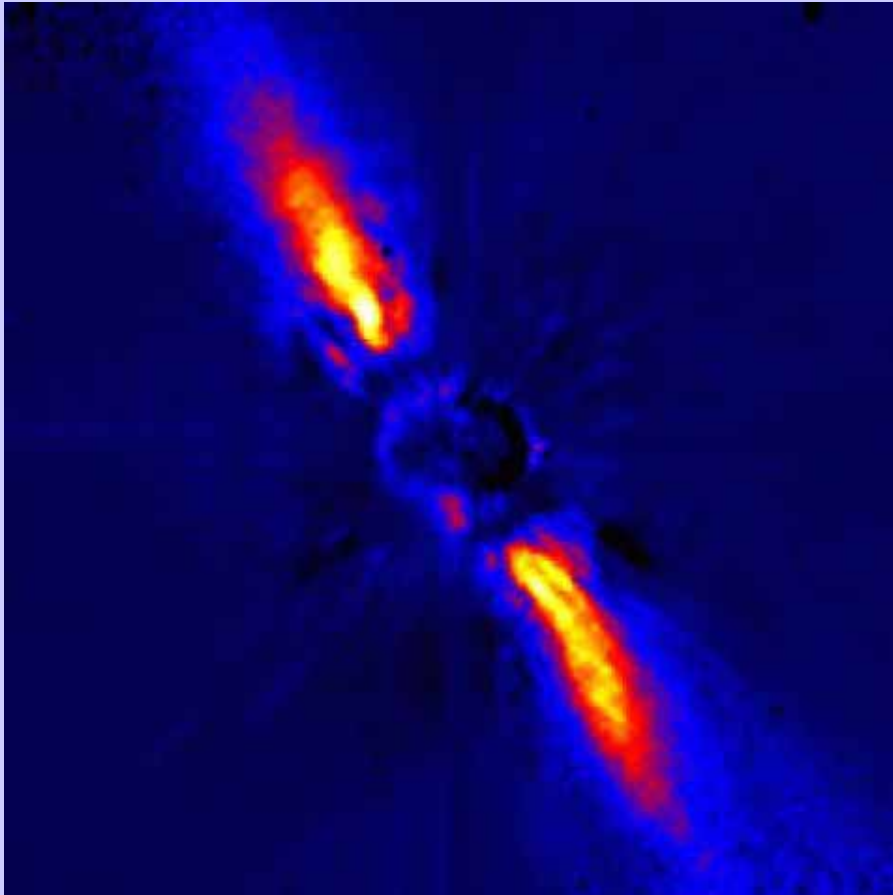
Gullies of Mars
From
Mars Global Surveyor



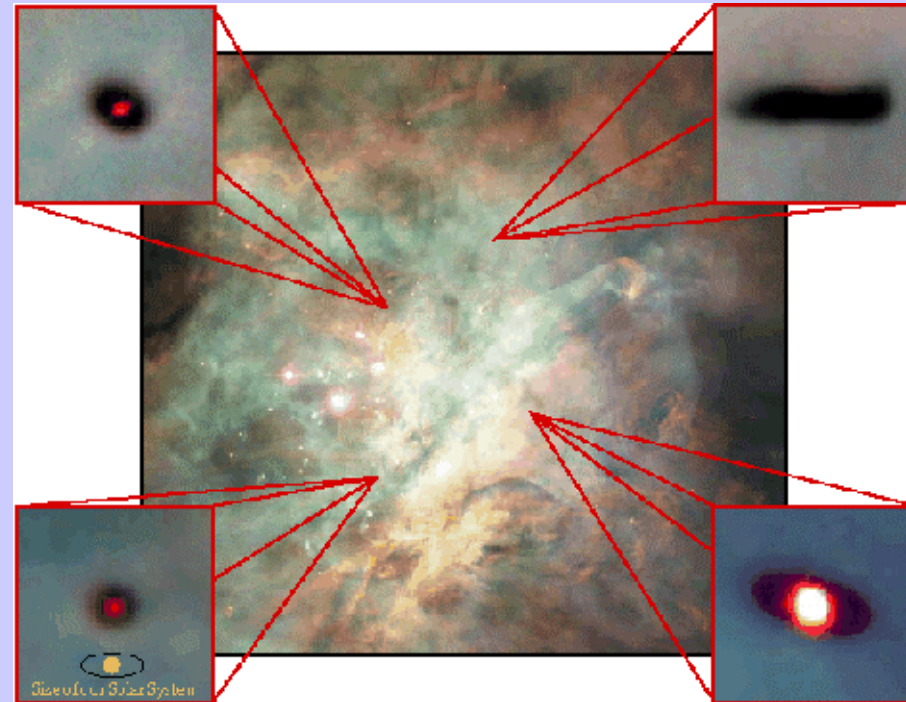
Malin Space Science Systems, MGS,
JPL, NASA

Circumstellar disks

Beta Pictoris

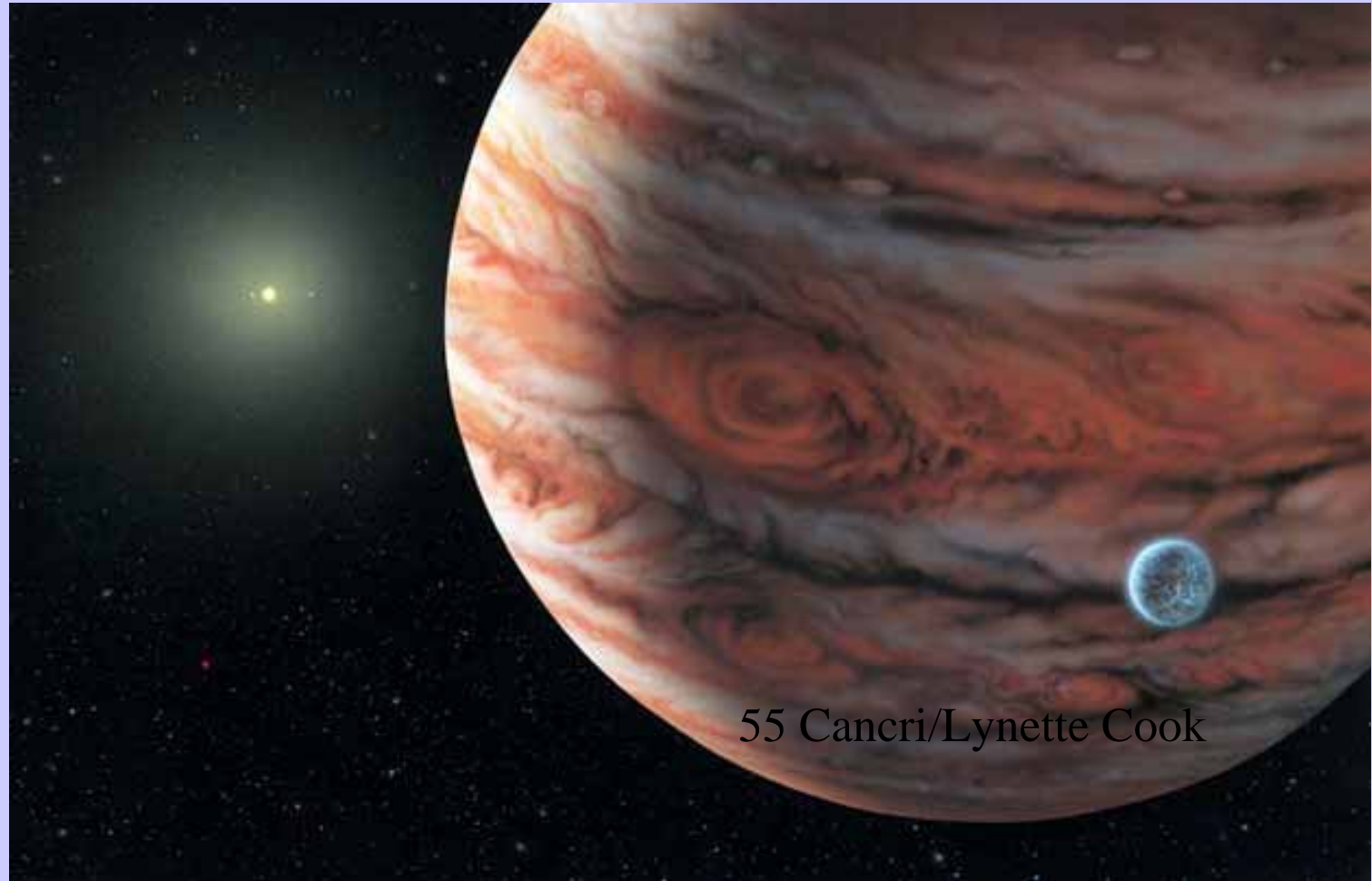


J.-L. Beuzit et al. (Grenoble Obs.), ESO



C. R. O'Dell and S. K. Wong, Rice U., WFPC2, HST, NASA

Real Planets!



55 Cancri/Lynette Cook

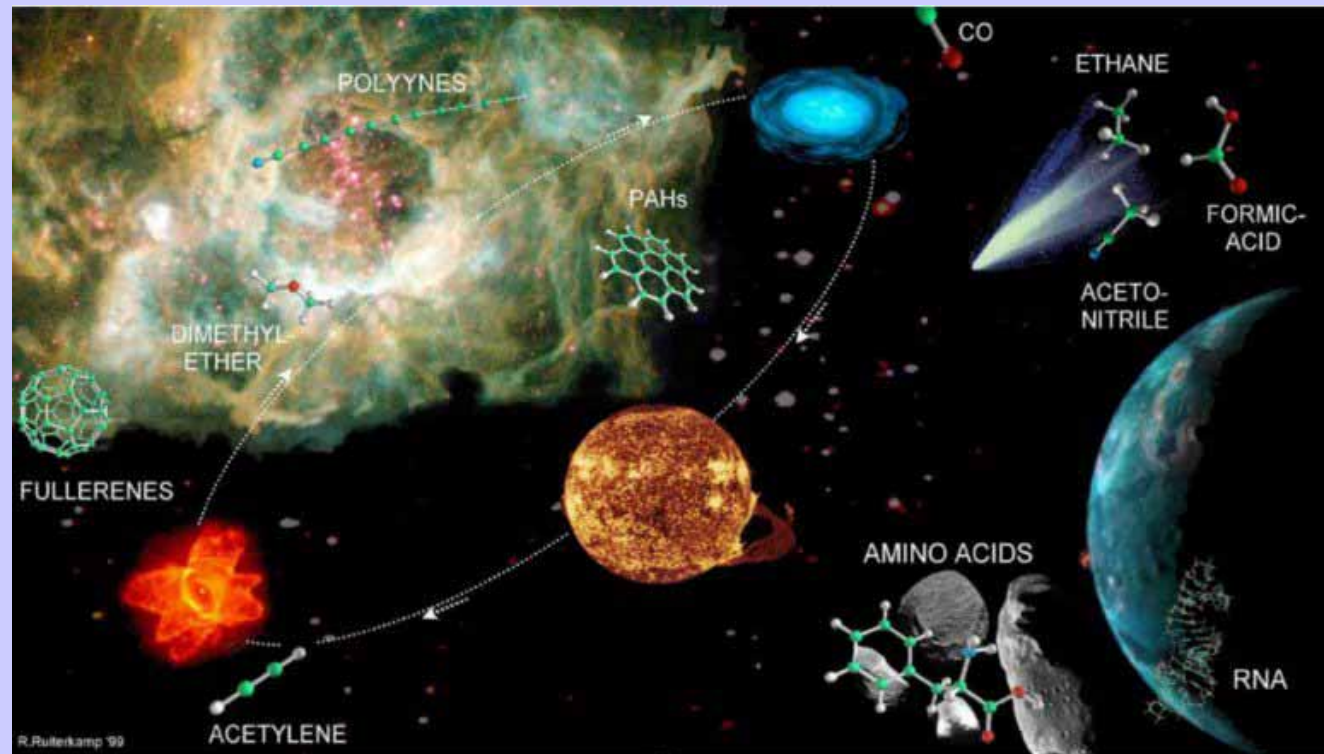
Origins of Life



Hydrothermal Vent
University of Victoria



Tube Worms
punaridge.org

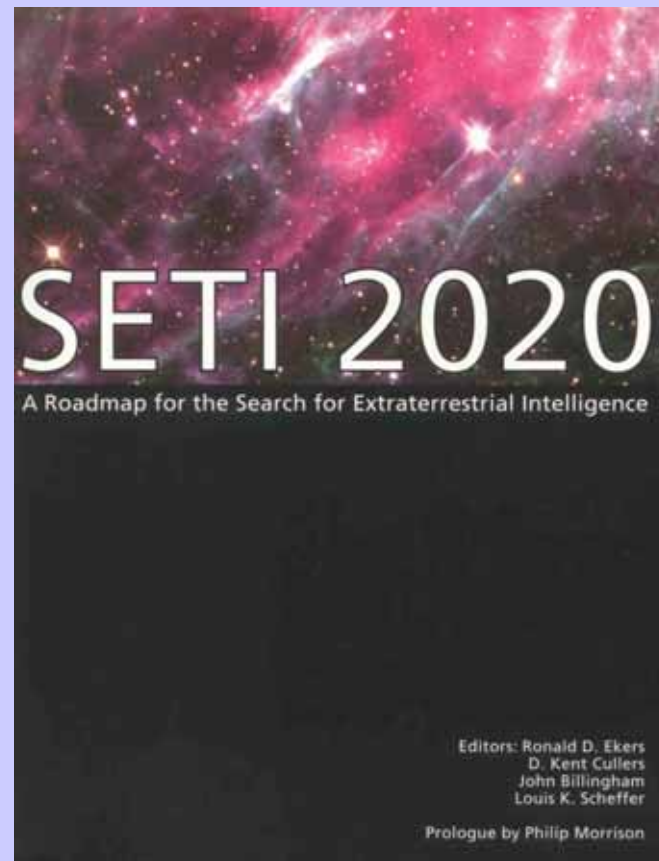


Interstellar Organics

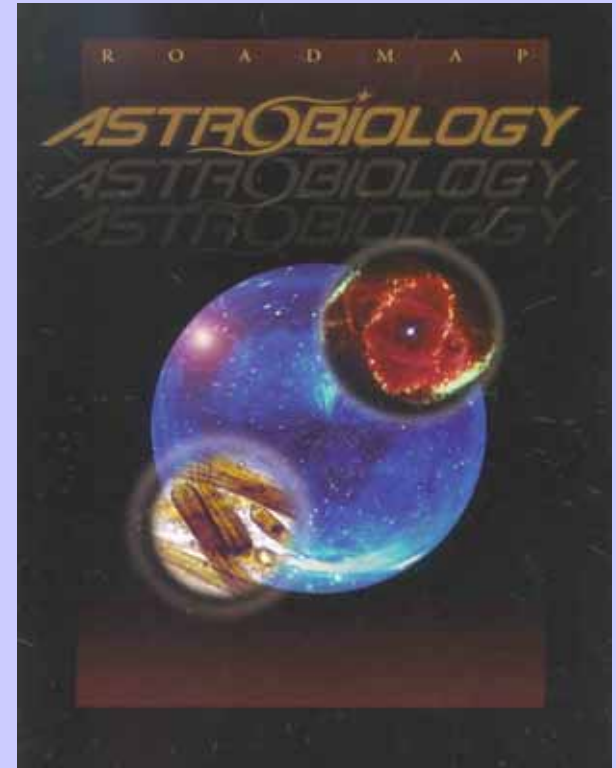
SETI



Allen Array



Astrobiology- Institutional Milestones



- 1995 May. NASA Ames named Astrobiology Lead
- 1996. NASA Strategic Plan Broaches Astrobiology
- 1998. Astrobiology Roadmap
- 1998 May. Eleven Institutions become charter members of Astrobiology Institute
- 1999 May. Baruch Blumberg Named NAI Director
- 2001. Four more Institutions join NAI
- 2002. September. Bruce Runnagar named NAI Director
Rosalind Grimes is Acting Director until 2003
- 2003. Twelve NAI Team Leads replace original 11
- 2003 Revised Astrobiology Roadmap

The NASA Vision

To improve life here

To extend life to there

To find life beyond

The NASA Mission

To understand and protect our home planet

To explore the universe and search for life

To inspire the next generation of explorers

... as only NASA can

Coalescence of a New Discipline

Planetary Systems

Circumstellar Disks
Extrasolar Planets
Kepler, SIM, TPF
Biosignatures
Theoretical studies

Origins of Life

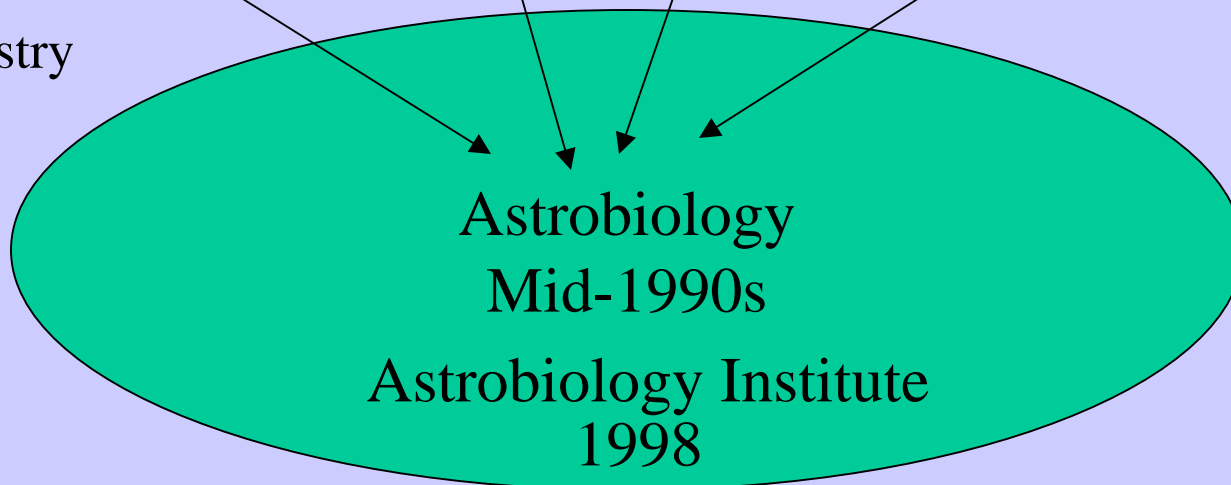
Genomics/Phylogenetic relationships
Life in Extreme Environments
Complex Organics Simulations and Obsns
Laboratory Prebiotic Experiments

Planetary Science

Mars Rock
Europa
Geochemistry
Biogeochemistry

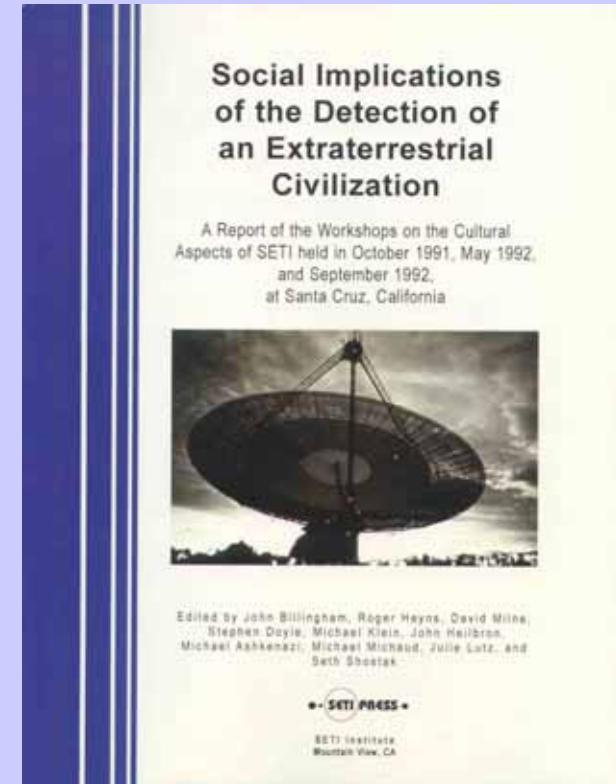
SETI

Allen Array
SETI at Home
SETI 2020 Roadmap



Implications of Astrobiology

Studies of Implications of Astrobiology

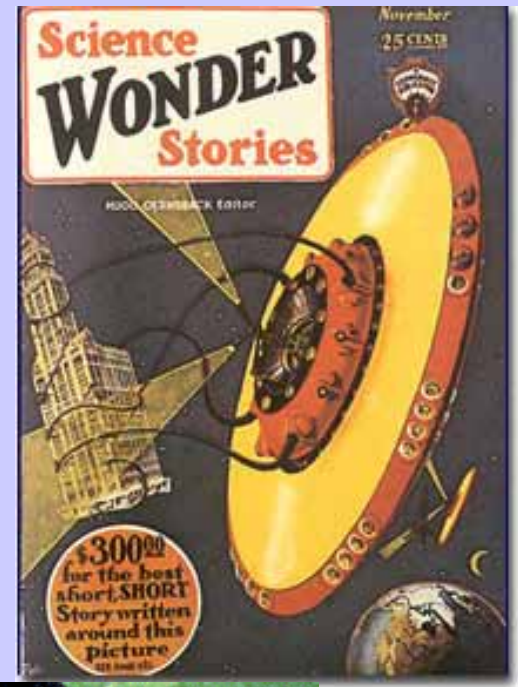
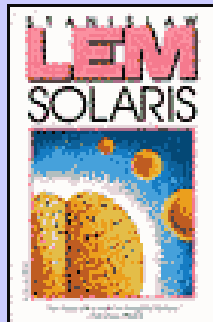


- 1991-1992 NASA CASETI Workshops
- 1999 NASA Workshop on Societal Implications of Astrobiology
- Templeton Foundation Workshops
- Foundation for the Future Studies
- AAAS Program of Dialogue Between Science and Religion

TABLE 1
STAGES IN WORLD VIEW DEVELOPMENT

Stage	Geocentric	Heliocentric	Galactocentric	Extraterrestrial/ Biophysical
Motivation	motion of planets anthropocentrism	motion of planets Neoplatonism geocentric problems	globular cluster distribution	Copernican theory cosmic evolution
Presentation Based on Observation	Eudoxus/ Aristotle 4th century BC	Copernicus 1543	Shapley 1917	Kepler (disproven) Lowell (disproven) Viking (unlikely) radio signal? Martian meteorite?
Elaboration	Ptolemy et al.	Galileo, Kepler, Newton, et al.	Trumpler, Oort, et al.	scientists
Opposition	antirationalists	geocentrists religious	Curtis, et al.	religious philosophical scientific
Exploration of Implications Outside Field	anthropocentric religions and philosophies	philosophical literary scientific	further proof of nonanthropo- centrism	all aspects of human knowledge
General Acceptance	4th century BC	1700	1930s	widely accepted 1750
Final Confirmation	disproven	1838 (stellar parallax = Earth motion)	1950s (radio maps of galaxy)	deciphered signal? UFO identified? life on Mars/ Europa, etc.? Martian meteorite?

ETI in Popular Culture



Two Chief World Systems 21st Century

The Physical Universe vs. The Biological Universe

Cosmic Evolution



Big Bang	Precambrian Biology
Galaxies	Complex Life
Stars	Intelligent Life
Biogenic Elements	Cultural Evolution
Planets	Civilizations
Chemical Evolution	Science and Technology
Origin of Life	Study of Life in the Universe

Cultural Evolution

Cultural Evolution must be seen as an Integral Part of Cosmic Evolution and the Drake Equation

The Drake Equation

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$



Astronomical



Biological



Cultural

Stapledon- Think Long-Term!

**Long-term “Stapledonian” Thinking may be Necessary
To Understand the Nature of Intelligence
In the Universe Today, if it is
Indeed Widespread**

**Humans not Accustomed to
Thinking on Cosmic Time
Scales for Biology and Culture!**



A Postbiological Universe?

- 1) The Maximum Age (A) of ETI is Several Billion Years**
- 2) The Lifetime (L) of a Technological Civilization is > 100 Years and Probably Much Larger**
- 3) In the Long Term Cultural Evolution Supersedes Biological Evolution, and Would Produce Something Far Beyond Biology**

Summary

- **The Biological Universe is a World View**
- **We are on the Brink of Deciding Between Two World Views**
- **Astrobiology is the Science that will Provide the Critical Data**
- **Either Way, there will be Long-term /Short-term Societal Impact**